WT Poon 潘永達
SC Ling 凌紹祥
AYW Chan 陳恩和
TWL Mak 麥永禮

Use of hair analysis in the diagnosis of heavy metal poisoning: report of three cases

三個利用毛髮析測法診斷重金屬中毒的病例

We report three paediatric cases of suspected heavy metal poisoning that presented with non-specific symptoms. Hair samples of the three patients were sent overseas for analysis; results showed abnormal levels of many elements, including some heavy metals. A diagnosis of heavy metal poisoning was made and chelation therapy was offered to each patient. Blood levels for some heavy metals were subsequently checked and all were within the normal range. The original diagnosis of heavy metal poisoning was therefore not substantiated. The patients did not have a history of exposure to heavy metals or specific clinical features of heavy metal poisoning. The non-invasive nature of hair analysis is tempting, but the validity of such testing in diagnosing heavy metal poisoning is questionable.

本文報告三個懷疑重金屬中毒的兒科病例，當中並無任何重金屬中毒症狀。患者的毛髮樣本送往海外進行化學分析，結果顯示一些重金屬及其他許多元素的含量水平不正常，從而斷定三位患者為重金屬中毒，並建議接受螯合療法的治療。之後對一些重金屬在血液中的含量進行測試，含量水平全部在正常範圍以內，因此，早前認為是重金屬中毒的診斷無法得到確定。病人從沒接觸過重金屬，也無任何重金屬中毒的臨床症狀。非侵入性的特點使毛髮析測法頗具吸引力，但用於診斷重金屬中毒的準繩度則成疑問。

Key words:
Hair/chemistry;
Metals, heavy;
Poisoning/diagnosis;
Reproducibility of results

關鍵詞：
毛髮／化學；
重金屬；
中毒／診斷；
結果的可複製性

Hong Kong Med J 2004;10:197-200

Princess Margaret Hospital, 2-10 Princess Margaret Hospital Road, Laichikok, Hong Kong:
Department of Pathology
WT Poon, MB, ChB
AYW Chan, MD, FHKAM (Pathology)
Department of Paediatrics and Adolescent Medicine
SC Ling, MB, BS, FHKAM (Paediatrics)
Department of Clinical Pathology, Tuen Mun Hospital, Tuen Mun, Hong Kong
TWL Mak, FRCPA, FHKAM (Pathology)

Correspondence to: Dr TWL Mak
(e-mail: makwl@ha.org.hk)

Introduction

The heavy metals that are most often implicated in human poisoning are lead, mercury, cadmium, and (although technically not a heavy metal) arsenic. People may come into contact with these and other heavy metals in industrial work, pharmaceutical manufacturing, and agricultural activity, as well as through accidental ingestion of contaminated products. Children may be poisoned as a result of inadvertent exposure—for example, from playing on contaminated soil or ingesting lead-based paint.

Apart from specific clinical features, the 'tissue effects' of heavy metal poisoning, such as proteinuria in mercury poisoning[1] and basophilic stippling of erythrocytes in lead poisoning, are useful in providing adjunctive diagnostic evidence.[2] Measuring the metal load in the body is an important approach in diagnosing poisoning and assessing its severity. However, because most heavy metals distribute unevenly within the body, the levels in the blood or urine may not reflect the levels in other organ systems. Despite this limitation, blood and urine tests are routinely used in clinical practice to diagnose heavy metal poisoning.[3-5]

Heavy metals in the body may accumulate in hair, which has been advocated to be a valuable specimen for diagnosing heavy metal poisoning. The non-invasive nature of hair analysis makes it an attractive option to both patients and physicians.[6,7] However, its validity has been repeatedly challenged.[8,9] Specimen contamination and other analytical problems render this test highly controversial.[10,11]

Case reports

We report three separate cases presenting with non-specific symptoms. Hair analysis was offered by the medical practitioners and a diagnosis of heavy metal poisoning was made based on the results.

Case 1

In January 1999, a 5-year-old boy who was noticed to have some reading difficulty presented to a private paediatrician, who made a diagnosis of dyslexia and recommended testing for trace elements to exclude any secondary cause. Some hairs were sent to an overseas laboratory in the United States. A total of 39 chemical elements, divided into three categories, were tested for. Among 15 elements in the first category, which were regarded as "toxic", mercury was present at 5.83 parts per million and was reported to be more than two standard deviations above the mean level. The level of another element in this category, aluminium, was almost more than two standard deviations above the mean. Of the 19 elements in the second category regarded as "nutrients", manganese, cobalt, selenium, and strontium were present in low amounts. Of the elements in the third category (classified as "other"), rubidium was more than two standard deviations above the mean level. No blood or urine heavy metal analysis was performed.

The paediatrician recommended chelation therapy for mercury and replacement therapy for some of the "nutrient" elements, but did not recommend any intervention for abnormal rubidium level. The patient's parents refused the treatment and consulted another clinician for a second opinion. The reliability of the hair analysis was questioned by the second clinician. A blood specimen was thus collected carefully to avoid contamination and was tested for whole blood mercury and serum aluminium by a local hospital laboratory. The whole blood mercury level was 46.6 nmol/L (reference level, <50.0 nmol/L) and the serum aluminium level was less than 0.12 µmol/L (reference range, 0.00-0.40 µmol/L). The results were confirmed by a second hospital laboratory. Mercury or aluminium poisoning was therefore not confirmed. The patient did not receive any treatment and developed normally thereafter.

Case 2

A 3-year-old boy with generalised epilepsy was treated by the paediatric team of the Princess Margaret Hospital using sodium valproate since September 2002. Development was otherwise normal. The patient's mother took him to visit a private paediatrician for a second opinion. This paediatrician suspected autism and advised testing the child's hair for heavy metal and nutritional element. The specimen was sent to an overseas laboratory, which was the same one mentioned in case 1, for testing. Fifteen heavy metals and nutritional elements were found in abnormal quantities, including aluminium, antimony, arsenic, lead, tin, mercury, nickel, and zinc. However, the child showed no signs or symptoms suggestive of metal poisoning, and gave no history of exposure to heavy metal. "Heavy metal removal therapy" (presumably chelation therapy) was offered. The parents were alarmed and returned to the hospital paediatric clinic for advice. A blood sample was collected and analysed for a number of heavy metals. The whole blood mercury and lead levels were <15.0 nmol/L and <0.20 µmol/L (reference range, 0.20-0.47 µmol/L), respectively; the serum copper and zinc levels were 22.1 µmol/L (reference range, 12.0-25.0 µmol/L) and 13.0 µmol/L (reference range, 11.2-20.8 µmol/L), respectively. Heavy metal poisoning was therefore not substantiated.

Case 3

A 6-month-old baby boy was observed by her mother to have feeding problems and drowsiness. The mother consulted a private paediatrician, who ordered a series of investigations, including hair analysis by the same overseas laboratory for heavy metal poisoning tests. Whole blood lead and mercury levels were also checked locally and the results were normal. However, hair analysis revealed 24 of 39 elements to be present in abnormal levels—for example, elevated levels of lead, mercury, and copper. On the other hand, the zinc level was low. The diagnosis was heavy metal poisoning and deficiency in certain nutritional elements. Blood mercury and lead levels were normal, but these results did not appear to have been factored in the prescribed treatment regimen: "mineral" 1 mL daily, *Enterococcus faecalis* two drops twice daily, and half a capsule a day of each of the following: 2,3-dimercaptosuccinic acid (DMSA), substance "alpha", and zinc supplements. We may assume that the DMSA was prescribed as chelation therapy, whereas zinc and "mineral" supplements were given for the suspected deficiencies. We did not know the exact nature of "alpha". It may have been "alpha-lipoic acid", which is an antioxidant used by some medical practitioners; it is also used by some alternative medicine practitioners to manage a number of conditions, such as chronic fatigue, diabetes mellitus, and metal poisoning.[12,13] *Enterococcus faecalis* is given by some practitioners as a 'probiotic'. Enteric feeding of this live microbial supplement is believed to have a beneficial effect on the digestive system by inhibiting the growth of pathogenic organisms.[14] The drugs were only given once because the baby spat them out. The mother, still concerned about the feeding problem, took the baby to a local public hospital for further assessment. It was found that the hole in the feeding teat was too small. After the hole was enlarged, the feeding problem resolved. Because heavy metal poisoning and deficiency of nutritional elements were concerns, blood specimens were tested for their mercury, lead, copper, and zinc content. The whole blood mercury level was 24.0 nmol/L, whole blood lead level was <0.20 µmol/L, serum copper level was 16.0 µmol/L, and serum zinc level was 17.0 µmol/L. The results were all normal. There were no signs or symptoms of heavy metal toxicity.

Discussion

Hair analysis for heavy metals and nutritional elements, despite being controversial, is offered by some laboratories in the US. In a report published in 2001, an estimated 225 000 hair tests for multiple elements were performed each year in the US by nine laboratories, together generating an annual gross revenue of US$9.6 million.[15] Commercial laboratories, nutrition consultants, and practitioners of alternative medicine often promote the use of hair analysis as a diagnostic tool in the investigation and treatment of a wide variety of diseases, and they use their findings to prescribe nutritional supplements and chelation therapy.

However, this practice is very controversial. It is the current policy of the American Medical Association to "oppose chemical analysis of the hair as a determinant of the need for medical therapy and support informing the American public and appropriate governmental agencies of this unproven practice and its potential for health care fraud."[16]

The US Agency for Toxic Substances and Disease Registry states that "for most substances, insufficient data currently exist that would allow the prediction of a health effect from the concentration of the substance in hair."[17,18]

The US Centers for Disease Control and Prevention have compared hair and blood samples from 189 children to assess the accuracy of hair analysis in screening for lead poisoning. The method had a 57% sensitivity and an 18% false-negative rate. The investigators concluded that measurement of lead content in hair is not an adequate method of screening for childhood lead poisoning. To obtain a reliable measure of individual lead exposure, the investigators concluded that it is necessary to assess the whole blood lead level.[19]

In 1999, Seidel et al[15] from the California Department of Health sent hair samples from a healthy individual to six commercial laboratories in the US (covering >90% of such tests for the whole country) to analyse a panel of elements. The results of many elements differed by as much as a factor of 10 among these laboratories. Five of the six laboratories found at least one element above normal, but none reported the same element. The authors concluded that hair analysis is unreliable.

From an analytical point of view, hair analysis is not a robust diagnostic tool for heavy metal poisoning. The specimen is prone to exogenous contamination because hair is a perfect binding medium for dust. Personal habits such as the use of different kinds of shampoo or hair dyes contribute to the variability.[19-21] Furthermore, there are no properly defined reference ranges, and there is a lack of proper accreditation and external quality assurance schemes for hair analysis. Consequently, one does not know which laboratory, if any, is reliable.

If cases of non-specific symptoms and signs are referred for hair analysis, the probability of actual heavy metal poisoning is low, and a large number of false-positive results can be expected. From a statistical point of view, if multiple elements are tested for simultaneously, some will be classified as 'abnormal' by chance alone. For example, if the central 95% of normally distributed analytical results are considered 'normal', then the statistical probability that at least one analyte in a panel of 39 will be classified as 'abnormal' is $[1-(0.95)^{39}]$, which equals 86%.[22] In our cases, hair analysis yielded many abnormal results and led to unnecessary additional diagnostic tests, potentially harmful treatment, and increased patient anxiety.

Conclusion

We have presented three cases of suspected heavy metal poisoning with non-specific symptoms. Diagnosis of heavy metal poisoning had been made on the basis of hair analysis. In case 3, the diagnosis was made despite normal blood results.

Diagnosis of heavy metal poisoning should be made only after meticulous investigation. The practice of hair mineral analysis is highly controversial. It is essential to confirm any seemingly abnormal hair analysis results by more reliable investigation methods, such as blood, serum, or urine analyses. In our opinion, hair metal analysis does not even qualify as a screening tool. Hair analysis should be considered only as an exploratory research method, and the results should not be relied on to diagnose heavy metal poisoning and nutritional deficiency. This practice is both dubious and potentially dangerous.

References

1. Kazantzis G. Mercury exposure and early effects: an overview. Medicina del Lavoro 2002;93:139-47.
2. Lopez Lopez RM, Martin Nunez G, Fernandez Galan MA, Gonzalez Hurtado JA. Anemia secondary to lead poisoning. Our experience with 12 cases [in Spanish]. Rev Clin Esp 2001;201:390-3.
3. Hong Kong Department of Health. Information sheet on mercury poisoning for doctors. Hong Kong: Hong Kong Department of Health; 2002.
4. Broadsheet No.36: Laboratory Investigation of Lead Exposure. Board of Education, The Royal College of Pathologists of Australasia, Australia, July 1995.
5. US Centers for Disease Control and Prevention (CDC). Screening young children for lead poisoning: guidance for state and local public health officials. Atlanta, GA: CDC; 1997.
6. Shamberger RJ. Validity of hair mineral testing. Biol Trace Elem Res 2002;87:1-28.
7. Puchyr RF, Bass DA, Gajewski R, et al. Preparation of hair for measurement of elements by inductively coupled plasma-mass spectrometry. Biol Trace Elem Res 1998;62:167-82.
8. Barrett S. Commercial hair analysis: Science or scam? JAMA 1985;254:1041-5.

9. Barrett S. Commercial hair analysis: a cardinal sign of quackery. Quackwatch website: http://www.quackwatch.org/01 QuackeryRelatedTopics/hair.html. Accessed 20 Nov 2003.
10. Frisch M, Schwartz BS. The pitfalls of hair analysis for toxicants in clinical practice: three case reports. Environ Health Perspect 2002;110:433-6.
11. Hindmarsh JT. Caveats in hair analysis in chronic arsenic poisoning. Clin Biochem 2002;35:1-11.
12. Patrick L. Mercury toxicity and antioxidants: Part 1: role of glutathione and alpha-lipoic acid in the treatment of mercury toxicity. Altern Med Rev 2002;7:456-71.
13. Schmid R. Alpha lipoic acid: the "universal antioxidant" that saves lives. Critical for diabetes and liver problems, alpha lipoic acid may be the most potent antioxidant yet discovered. Alternative Medicine Center of Connecticut website: http://www.drrons.com/alpha_lipoic.html. Accessed 20 Nov 2003.
14. Ohhira I. Properties of anti-MRSA component in the culture broth of E.faecalis TH 10. Probiotics Central website: http://www.buyprobiotics.com/Results_of_Antimicrobial_Activity_Study.htm. Accessed 14 Apr 2004.
15. Seidel S, Kreutzer R, Smith D, McNeel S, Gilliss D. Assessment of commercial laboratories performing hair mineral analysis. JAMA 2001;285:67-72.
16. American Medical Association (AMA). Hair analysis: a potential for abuse. Policy No. H-175.995. Chicago: AMA; 1994.
17. Agency for toxic substances and disease registry (ATSDR). Hair analysis panel discussion: exploring the state of the science. Summary report. Atlanta, GA: ATSDR; 2001.
18. Yoshinaga J, Imai H, Nakazawa M, Suzuki T, Morita M. Lack of significantly positive correlations between elemental concentrations in hair and in organs. Sci Total Environ 1990;99:125-35.
19. Esteban E, Rubin CH, Jones RJ, Noonan G. Hair and blood as substrates for screening children for lead poisoning. Arch Environ Health 1999; 54:436-40.
20. Paschal DC, DiPietro ES, Phillips DL, Gunter EW. Age dependence of metals in hair in a selected U.S. population. Environ Res 1989; 48:17-28.
21. Miekeley N, Dias Carneiro MT, da Silveira CL. How reliable are human hair reference intervals for trace elements? Sci Total Environ 1998;218:9-17.
22. Galen RS, Gambino SR. Beyond normality: the predictive value and efficiency of medical diagnosis. New York: John Wiley and Sons; 1975.